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SECOND AUTUMN WORKSHOP ON
CLOUD PHYSICS AND CLIMATE

(23 November - 18 December 1987)

CLOUD AND PRECIPITATION PROCESSES

PART 1

CLOUD CLIMATOLOGIES

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Workshop in Cloud Physics and Climate

23 November - 18 December 1987

CLOUD AND PRECIPITATION PROCESSES

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Part I. Cloud Climatologies.

I. CLOUD CLIMATOLOGIES.

Cloud and precipitation processes

Precipitation climatologies

Hughes, 1984; JCAM p.724 I/1

TABLE 1. Characteristics of the global cloud climatologies available at present. Data compiled from the sources referenced.

Author	1 Spatial resolution	2 Time scale	3 Time of day	4 Temporal coverage by maps	5 Projection	6 Contour interval	7 Spatial coverage	8 Zonal averages	Source of cloud data	Comparisons	Motivation
(i) Cloud climatologies compiled from conventional surface observations											
Brooks, 1927	10°	?	40% between 7 and 10 LST	No maps	NA	NA	G	Annual monthly (D)	1000 land stations, shiplogs, expedition data	Arrhenius, 1896	To describe world cloud cover
Shaw, 1936	10°	?	As in Brooks, 1927	Annual and monthly	PS	T	G	No	As in Brooks, 1927	No	Textbook
Haurwitz and Austin, 1944	?	?	?	Jan and Jul	U	T	G	Quotes Brooks, 1927	? conventional surface observations	No	Textbook
Landsberg, 1945	?	?	?	Bi-monthly	H/Me	T	G	No	? conventional surface observations	No	Textbook
Telegadas and London, 1954	5° lat & 10° long	?	1200 GMT	Winter and Summer	PS	T	NH	Winter Summer (D)	McDonald (1938), plus station data on cloud type/height	No	Climate modeling
Seide, 1954	5° lat & 10° long	?	1200 GMT	No maps	NA	NA	NH	Spring Fall (D)	McDonald (1938), plus station data on cloud type/height	Brooks, 1927	Climate modeling
London, 1957	5° lat & 10° long	?	1200 GMT	Four seasons	PS	T	NH	4 Seasons (D)	McDonald (1938), plus station data on cloud type/height	No	Climate modeling
Hastenrath and Lamb, 1977	1°	1911–70	DA	Monthly	SC	T	Atlantic and Pacific Oceans	No	Ship observations (includes low cloud amount)	No	Compilation of climatological atlas

(ii) Cloud climatologies compiled from satellite data											
Arking, 1964	?	12/7/61–10/9/61	SP day	No maps	NA	NA	QG	For time available	TIROS III 1447 photographs—simple threshold technique	London, 1957	Investigating techniques to derive cloud amounts from satellite data
Rasool, 1964	?	12/7/61–10/9/61	SP night	No maps	NA	NA	QG	For time available	TIROS III infrared data	Arking 1964, Haurwitz and Austin, 1944	
Taylor and Winston, 1968	5°	1/2/67–1/2/68	SP day	Seasonal monthly	Me	11 Brightness levels	G	No	ESSA photographic brightness data	No	
Kornfeld and Hasler, 1969	?	1967	SP day	Seasonal	PS/ Me	Brightness levels	G	No	ESSA brightness data	No	
Miller and Feddes, 1971	?	1967–71	SP day	Annual seasonal monthly	PS/ Me	5 levels	G	Compiled by Schutz and Gates 1971–72	ESSA "brightness" data "calibrated" against surface observations	No	
Bean and Somerville, 1981	2.5°	1974–77	SP day	Annual seasonal	SC	η and γ	G	No	Cloud estimated from NOAA SR system albedo—cloud frequency observations modeled with beta distribution	No	
Chahine, 1982	4° lat 5° long	1–7 Jan 1975	SP	7-day average	?	T	G	Yes	VTPR data using a radiative transfer technique	Sadler, 1969	
(iii) Cloud climatologies compiled from satellite-derived nephanalyses											
Clapp, 1964	4°	1/3/62–1/2/63	SP day	Annual seasonal	Me	T	G	Yes	TIROS nephanalyses	Arking, 1964, Vowinckel and Van Loon 1957, Landsberg, 1945	
(a) Sadler, 1969 (b) Sadler *et al.* 1976	2.5°	a) 1/2/65–1/1/67 b) 1/1/65–1/1/72	SP day	Annual monthly	Me	neph-code	30° North and South	Annual monthly	TIROS nephanalyses	Landsberg, 1945, Clapp, 1964, and rainfall data	
Godshall *et al.* 1969 Godshall, 1971	2°	1/8/62–1/8/68	SP day	4 monthly	SC	T	Pacific Ocean only	No	TIROS and ESSA nephanalyses	Surface observations	

TABLE 1—(*Continued*)

Author	1 Spatial resolution	2 Time scale	3 Time of day	4 Temporal coverage by maps	5 Projection	6 Contour interval	7 Spatial coverage	8 Zonal averages	Source of cloud data	Comparisons	Motivation
(iv) Cloud climatologies compiled for climate modeling using a variety of data sources											
Sherr *et al.*, 1968	NA	Greater than 10 years	DA	No maps (see text)	NA	NA	G	NA	Used maps of satellite and surface mean cloud to define cloud climatological regions	No	Simulation of global cloud cover
Newell, 1970 (Dopplick, 1972)	10°	(a) 1967–68 (b) 1964	?	No maps	NA	NA	G	Monthly	(a) Cram, (b) ETAC (TIROS nephanalyses), (c) Gabites, 1960, (d) London, 1957. (see text)	No	Climate modeling
van Loon, 1972	?	?	?	Jan, Jul	PS	20%	SH	Jan and Jul	Brooks, 1927; Landsberg, 1945; Vowinckel and Van Loon, 1957; Clapp, 1965; Sadler, 1969, National climate atlases.	No	Climate modeling
Schutz and Gates, 1971 and 1972	4° lat and 5° long	(a) 1963/68 (b) 1967/70	(a) 0000–1200 (b) 1400 LST	Jan Jul	SC	T	(a) 90–15°N (b) QG	Jan Jul	(a) ETAC (1971) surface and satellite observations (b) Miller *et al.* (1970), as in Miller and Feddes, 1971	No	Climate model comparison
Berlyand & Strokina 1980a, b	5°	30 years	daytime	Monthly (D)	H	T	G	Monthly	McDonald, 1938, surface and satellite observations, *e.g.*, Sadler, 1969 and Miller and Feddes, 1971	Extensive comparison of zonal averages	Climate modeling
(v) Recent three-dimensional (i.e., cloud amount with height) cloud climatologies compiled for climate modeling											
Becker, 1979	10°	(Jul 1972 Jan 1974)	SP day	Jan Jul	SC	20%	QG	Jan Jul	NOAA II data, using threshold technique of Anderson, 1974	No	Climate modeling
Meleschko, 1980	10°	Jul	daytime	Jul	SC	T	G	Jul	Derived cloud amount with height using data of Berlyand and Strokina, 1980b and Vonder Haar and Ellis, 1974	London, 1957	Climate modeling

1. Spatial resolution or spatial average of cloud climatology.
2. Time scale of the observations included in the climatology.
3. Time of day of the observations. DA = diurnal average, SP = satellite pass (either day or night if polar orbiter).
4. Temporal average for which maps are available: D = numerical data available.
5. Cartographic projection for which maps are available: PS = polar-stereographic, H = Hammer, Me = Mercator, SC = Simple cylindrical, U = Unknown.
6. Contour interval used on map, T = tenths or 10% intervals.
7. Spatial coverage, G = global, QG = quasi-global, NH = Northern Hemisphere, SH = Southern Hemisphere.
8. Time period for which zonal averages are available: (D) = numerical data available.

NA = not applicable.

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increased proportion of sea to land at these low latitudes could result in less representative surface cloud observations compared to the satellite observations. Alternatively, these differences could be indicative of interannual cloudiness variations. At most latitudes, as expected, the climatology with the highest cloud amount estimate is that of Berlyand and Strokina (1980b) and the lowest cloud amounts are reported by Miller *et al.* (1970).

The range of cloud amount estimates for each latitude zone (Table 3) and also the latitudinal variation in this range (range: January, 9–30%, July, 1–23%) highlights the uncertainty of the current specification of total cloud amount. These disparities emphasize the need for considerable caution when using any one cloud data set.

5. Conclusions

Recent model studies have emphasized the influence of cloud specification on the computed model parameters. Meleshko and Wetherald (1981) showed that using a geographical cloud distribution rather than a zonally averaged cloud amount can considerably improve the simulation capability of a general circulation model. Meleshko and Wetherald found that using a geographical cloud distribution increased the continental surface temperature by 2–4 K, decreased the surface pressure over continents and increased surface pressure over oceans. Shine (1981) demonstrated substantial differences in the calculated zonally-averaged radiation budget using either Dopplick (1972) or London (1957) cloud amount with height data. These results suggest that the correct specification of cloud amount is important for accurate climate modeling. This review has illustrated the wide range in the available global cloud climatologies. *There is, at present, no unique and/or generally agreed on global cloud climatology.*

The differing observational systems, resolution of the original data and summarizing procedures employed can result in different cloud amount distributions. The magnitude of cloud amount appears to be much more variable than the geographical pattern of cloud amount. There is general agreement about the location of cloud amount maxima and minima. The mean cloud amount is partially dependent on the spatial and temporal sampling and averaging scales inherent in the observations and over which averages are made. The size of the spatial average in relation to cloud size determines the shape of the cloud amount frequency distribution and, hence, influences the calculated mean cloud amount and its variability (Hughes and Henderson-Sellers, 1983). Zonal averages of cloud amount fail to reveal the complexities of the geographical distribution of total cloud amount. The limited coverage and variety of techniques used to produce the cloud climatologies does not allow accurate year to year global cloud differences to be detected.

Global cloud distribution is more complex than originally suggested by the climatologies based on surface observations alone. The satellite-derived observations demonstrate a detailed spatial variability of total cloud amount absent in the surface-based climatologies, due mainly to the inhomogeneous distribution of observation points. The location of continental low cloud amount is the most consistent feature of all climatologies. The location of cloud-free and very cloudy areas shows more agreement than the amount or location of intermediate cloud amounts. Cloudy and cloud-free areas are likely to be more "accurately" observed by both satellite and surface-based techniques than intermediate cloud amounts (Hughes, 1982). The areas of most disagreement between the climatologies appear to be the oceanic and polar regions.

Satellite and surface observations of total cloud amount are complementary. *It is unreasonable to expect cloud climatologies compiled from different types of observations to be identical.* Cloud climatologies including both surface and satellite cloud observations have to be interpreted with considerable care. In certain situations, however, joint observations may be necessary to estimate cloud amount accurately.

This review emphasizes the limitation of all the cloud climatologies currently available. The cloud climatologies described here represent different attempts to summarize the real world cloudiness. They vary widely in their ability to represent reality. It is important that users of cloud climatologies realize the range of different cloud observations available and thus the likely amplitude of the various cloud specifications.

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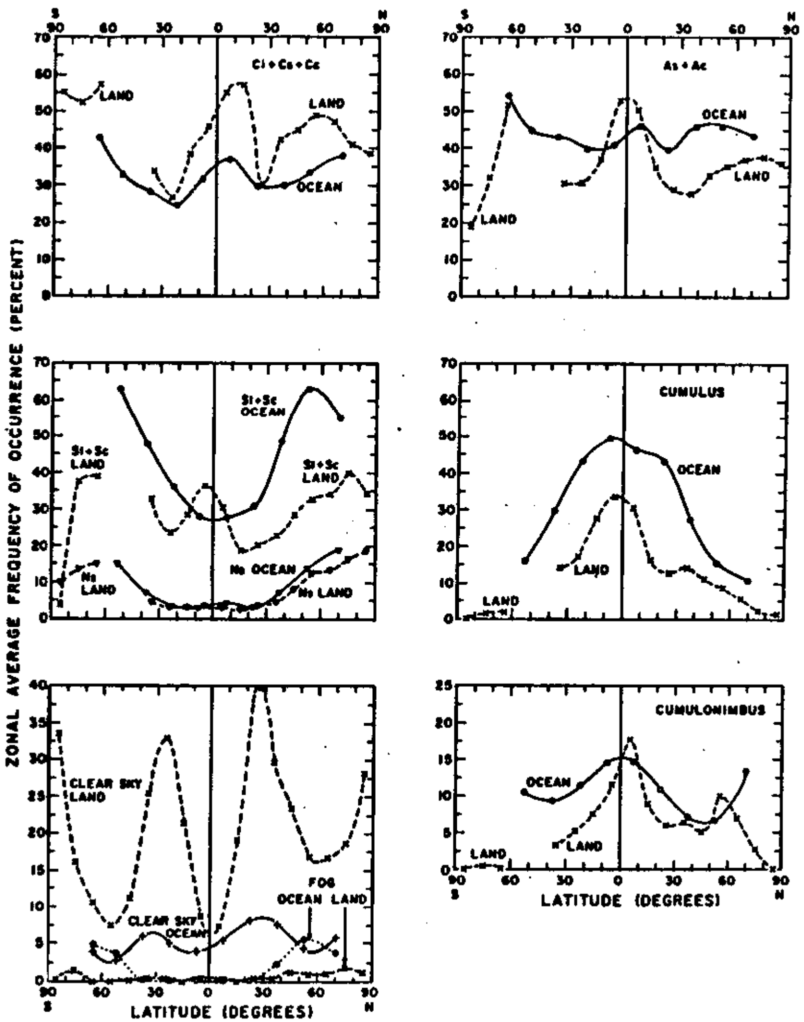

FIG. 1. Zonal, annual average frequency of occurrence of each cloud type, of clear sky, and of sky obscured due to fog, for land and ocean parts of each zone. ["Frequency of occurrence" is the fraction of weather observations in which a cloud type was reported present, given that it was possible to see whether it was present, irrespective of the fraction of the sky actually covered by that cloud.] A smooth curve is drawn through the points, which represent 10° zones over land and 15° zones over ocean (except for the high-latitude ocean zones 60°–80° N and 60°–70°S). The points are averages of all four seasons. Clear sky, fog, and cumulonimbus frequencies are plotted in the lower frames on an expanded scale. Gaps appear in most of the plotted values for land at 40°–60°S because the small amount of land there (less than 5%) often resulted in unrepresentative or meaningless zonal averages.

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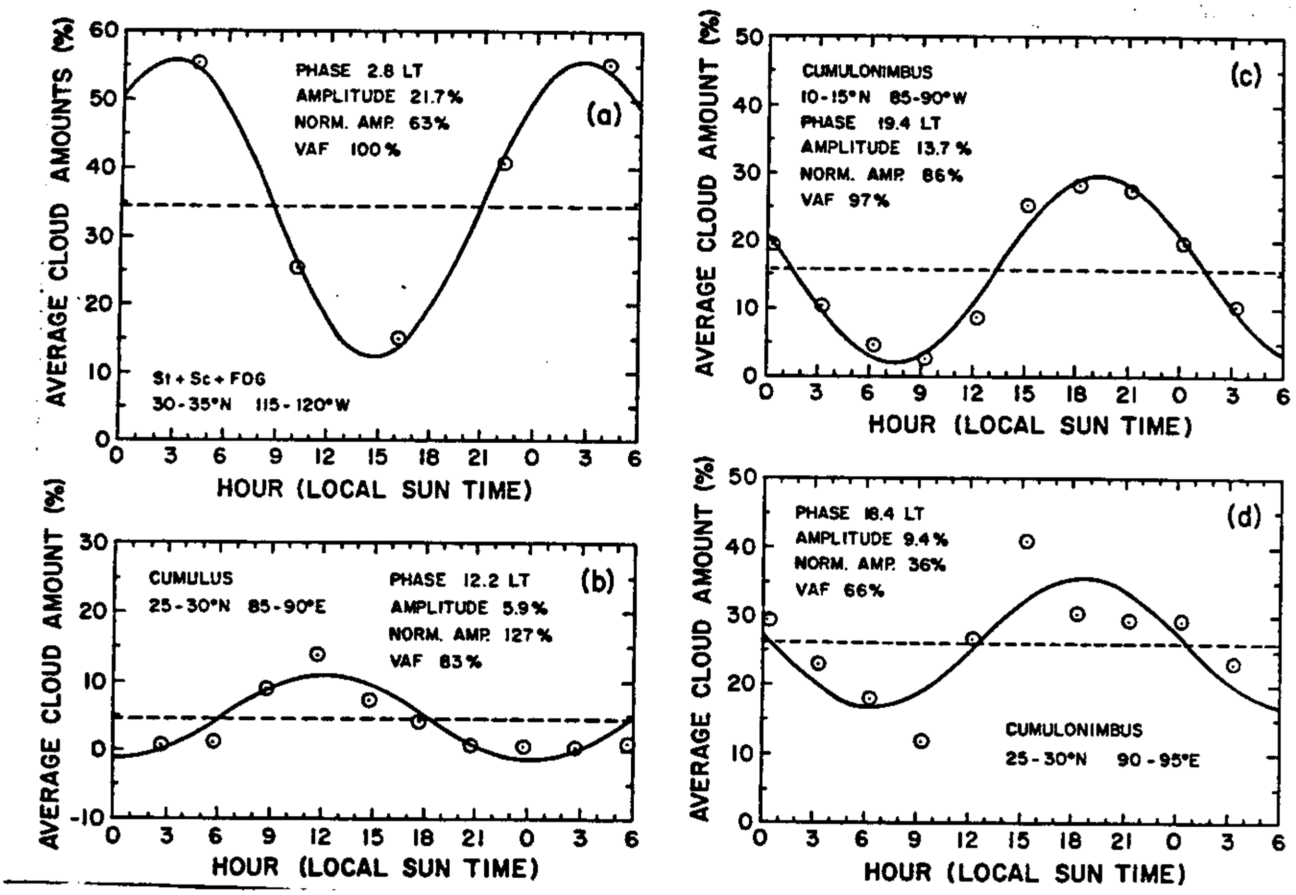

Figure [illegible]. Examples of diurnal cycles. All are for JJA 1971-1981. A cosine curve (solid line) is fitted to the four or eight data points shown. Phase is the local time of maximum of the cosine curve (mean solar time for the center of the 5° x 5° box.) The diurnal mean is shown as the dashed line. Amplitude is given in percent cloud cover. Normalized amplitude is the amplitude as a percentage of the mean. "vaf" is the percent of the total variance which is accounted for by the cosine curve.

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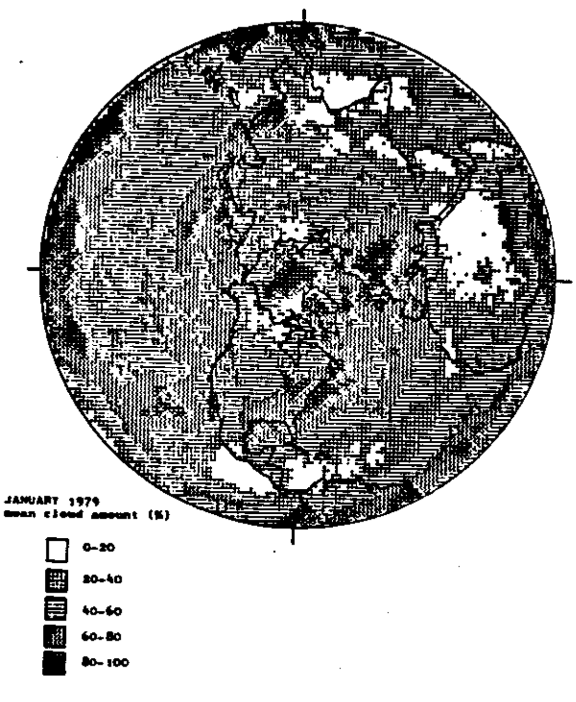
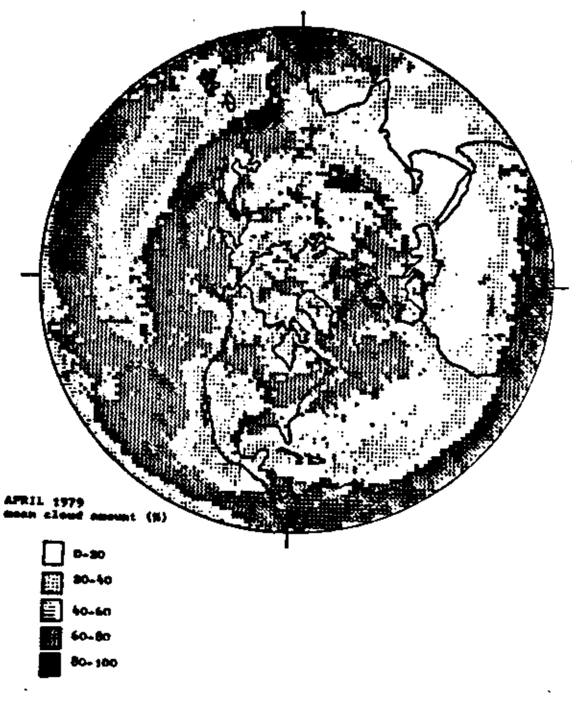
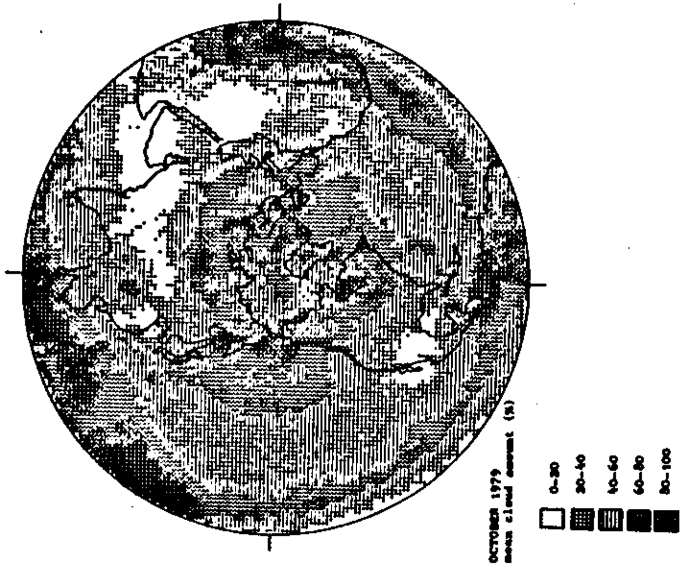






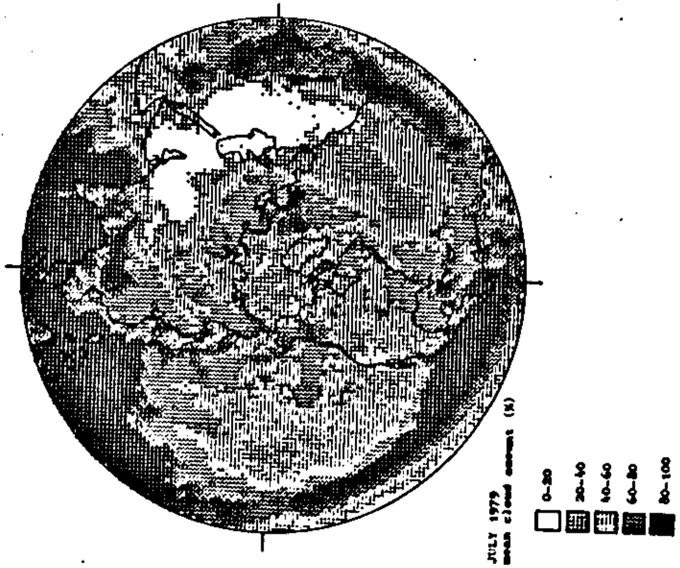
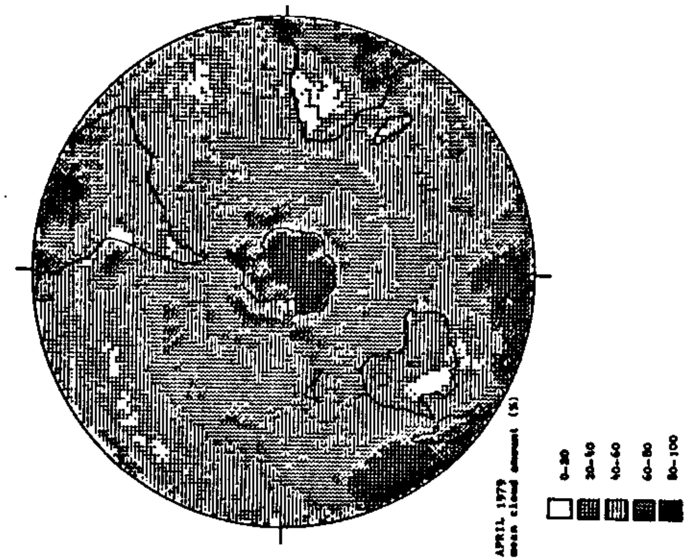
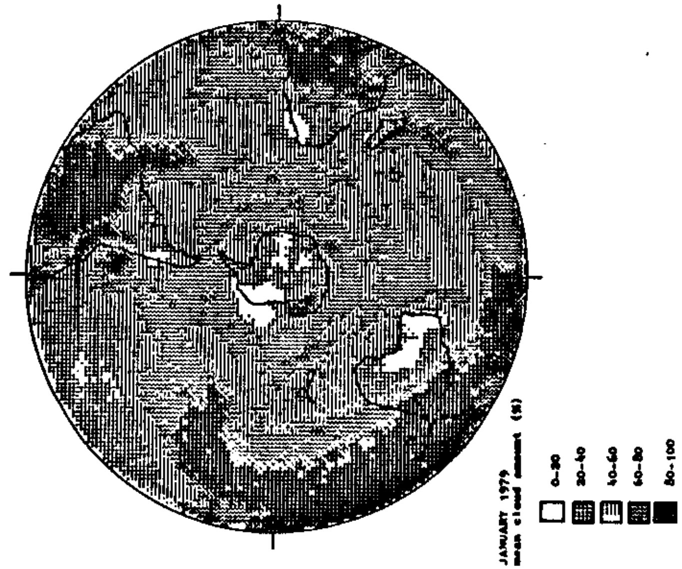


FIG. 3. (*Continued*) As in Fig. 2 but for the Northern Hemisphere.





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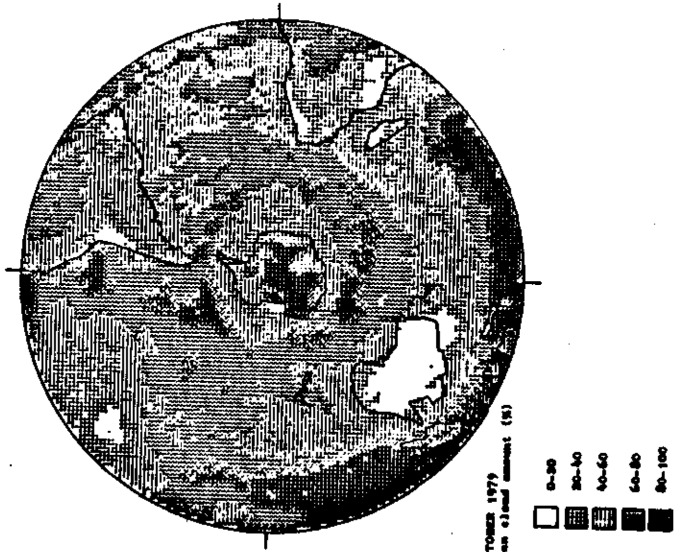

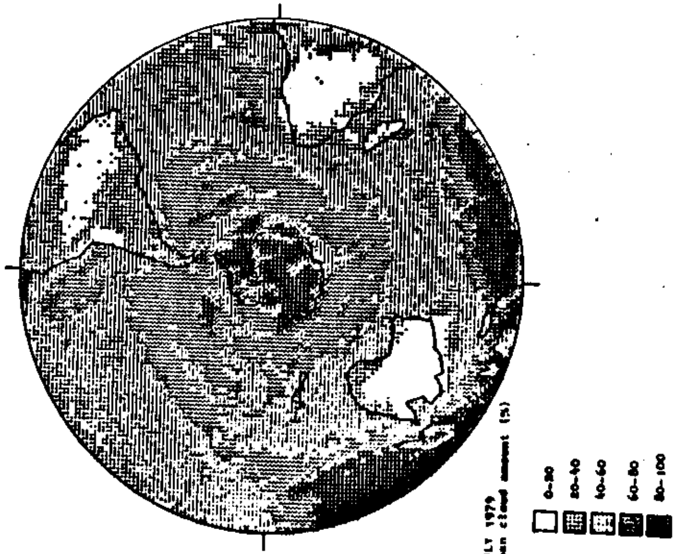

FIG. 2 (*Continued*) Monthly mean 3D-nephanalysis cloud amounts in the Southern Hemisphere for January, April, July and October 1979.

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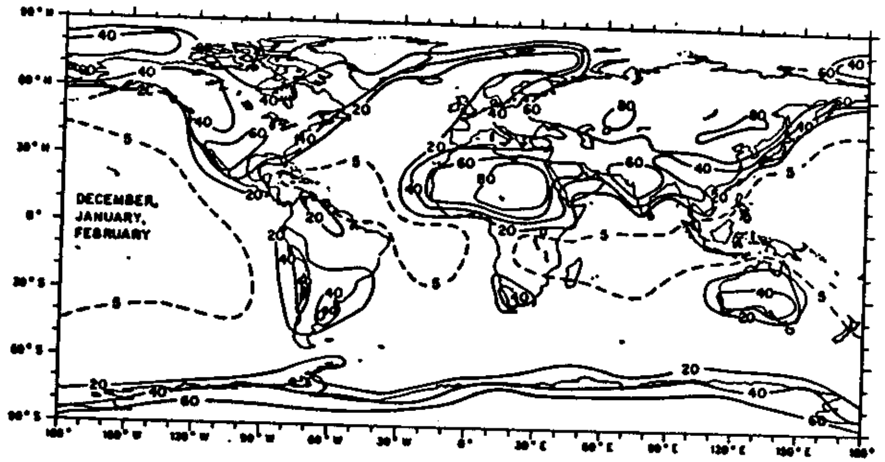
WARREN et al 1985 JCAM p658



Given Ci/Cs/Cc, Probability (Percent) That No Other Cloud Is Present

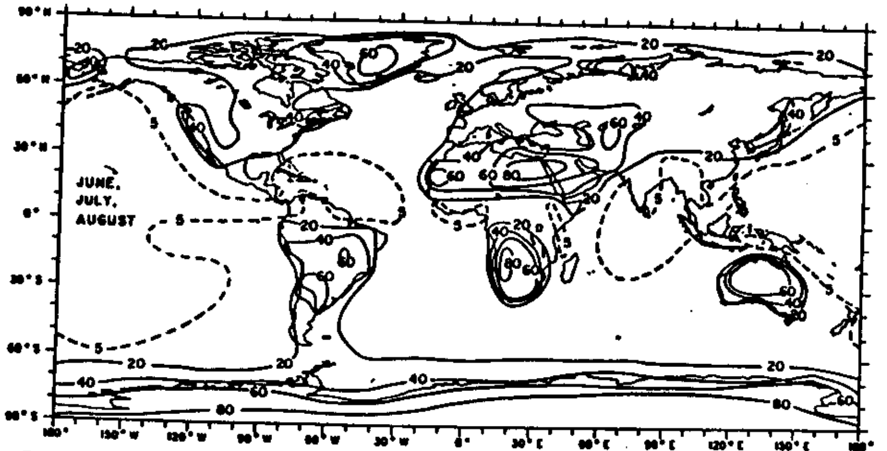


FIG. 2. Given that cirrus is present, this is the probability that no other cloud is present in the ground-observer's field of view. Results from Maps 12 of both the land and ocean atlases (Hahn *et al.*, 1982; 1984) were merged and contoured. Some smoothing of the point values was done for the purpose of contouring.

SLINGO, 1987 QJRMS p.895

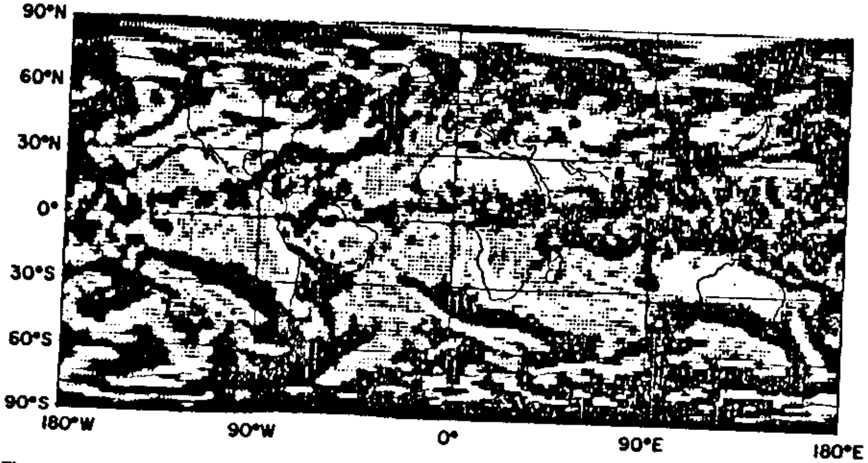


Figure 11. Distribution of total cloudiness from the model for day 5 of the forecast from 12 GMT on 11 June 1979. Compare with Fig. 12.

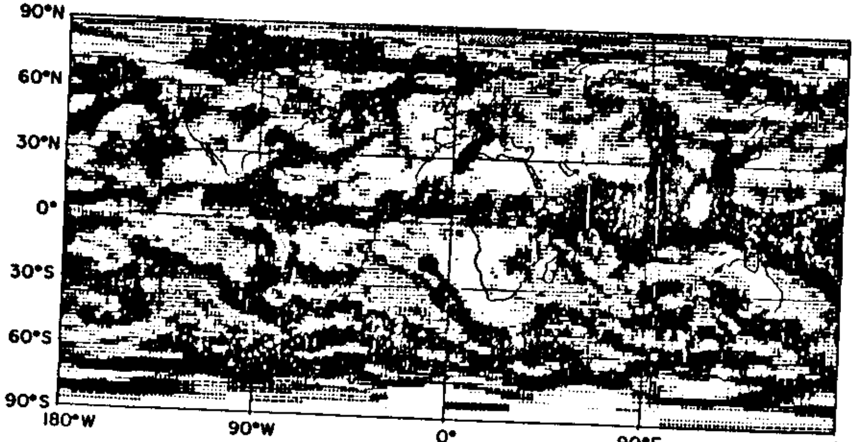
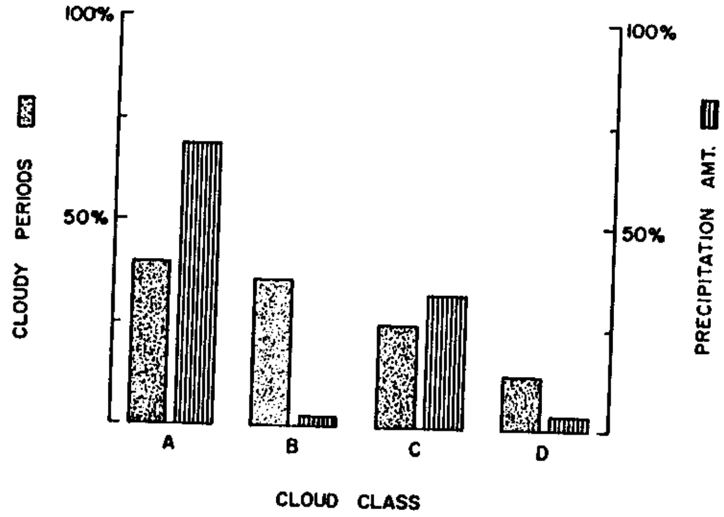
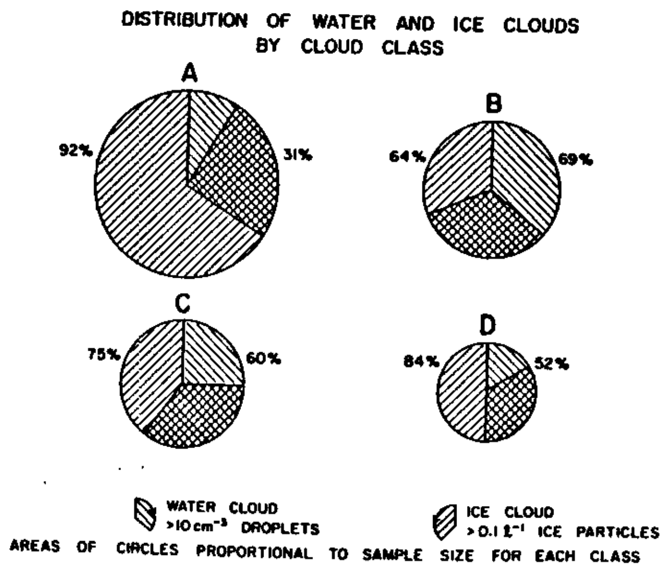


Figure 12. Distribution of total cloudiness derived from Nimbus 7 data for 16 June 1979, local noon.





This classification is based on 6 factors: (1) the visual appearance of the cloud systems, (as observed from aircraft and from the ground), (2) the in-situ observations by aircraft of cloud dynamics and microphysics, (3) the radar signatures of the systems, (4) satellite imagery, (5) precipitation amounts and patterns, and (6) the thermodynamic and dynamic state of the atmosphere. The first three of these factors constituted the primary basis for the classification; the other three were used to support the validity of the classification in terms of synoptic and mesoscale features.

CLASS A: Ns; merging layers of Cs and As, or Cs and Ac

These situations generally produce widespread precipitation of relatively low intensity but of relatively long duration. Some convection may be embedded in these clouds - usually at lower levels in the clouds. The sub-class AW refers to cases with cloud-top temperatures warmer than -18°C; sub-class AC refers to cases with colder cloud tops.

CLASS B: St, As; Cu hum; Sc; Ac. These clouds are shallow (<2 km depth) and can be in isolated small elements, larger patches, or in fairly extensive layers. They usually produce very little or no precipitation. The lifetimes of these clouds vary from quite short (<15 min) for Cu hum, to several hours for the more extensive layers.

CLASS C: Cu med; Cu con. This class refers to fairly vigorous convective clouds which are usually isolated, but sometimes emerge from more contiguous layers of shallower clouds. The spacing between isolated Cu towers is from one to several times the cloud diameter; when closely spaced the individual towers rise in succession. Lifetimes of individual clouds are roughly from 15 min to 1 hr, being limited by evaporation (dispersal) or by precipitation. Precipitation is usually spotty and is in bursts (showery).

CLASS D: Cb calv. These are large convective storms producing heavy showers at widely separated locations over lifetimes of 30 min to 2 hrs.

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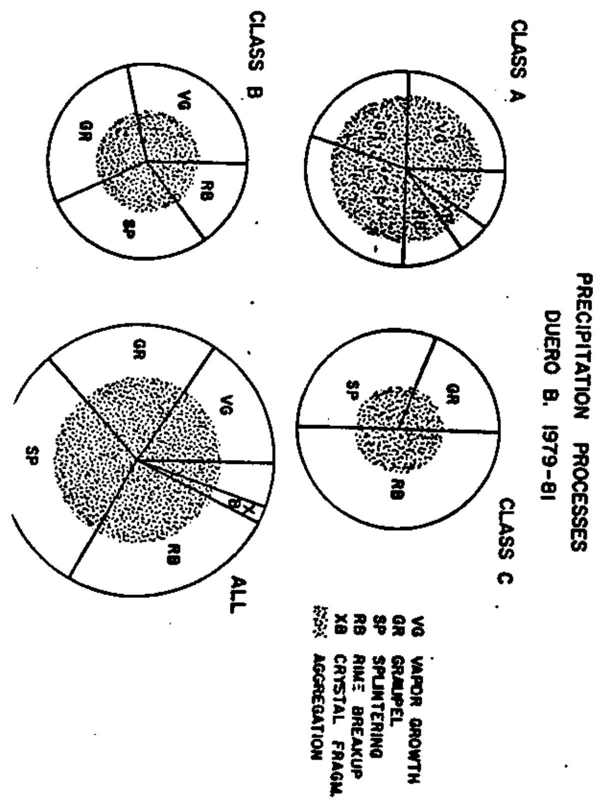

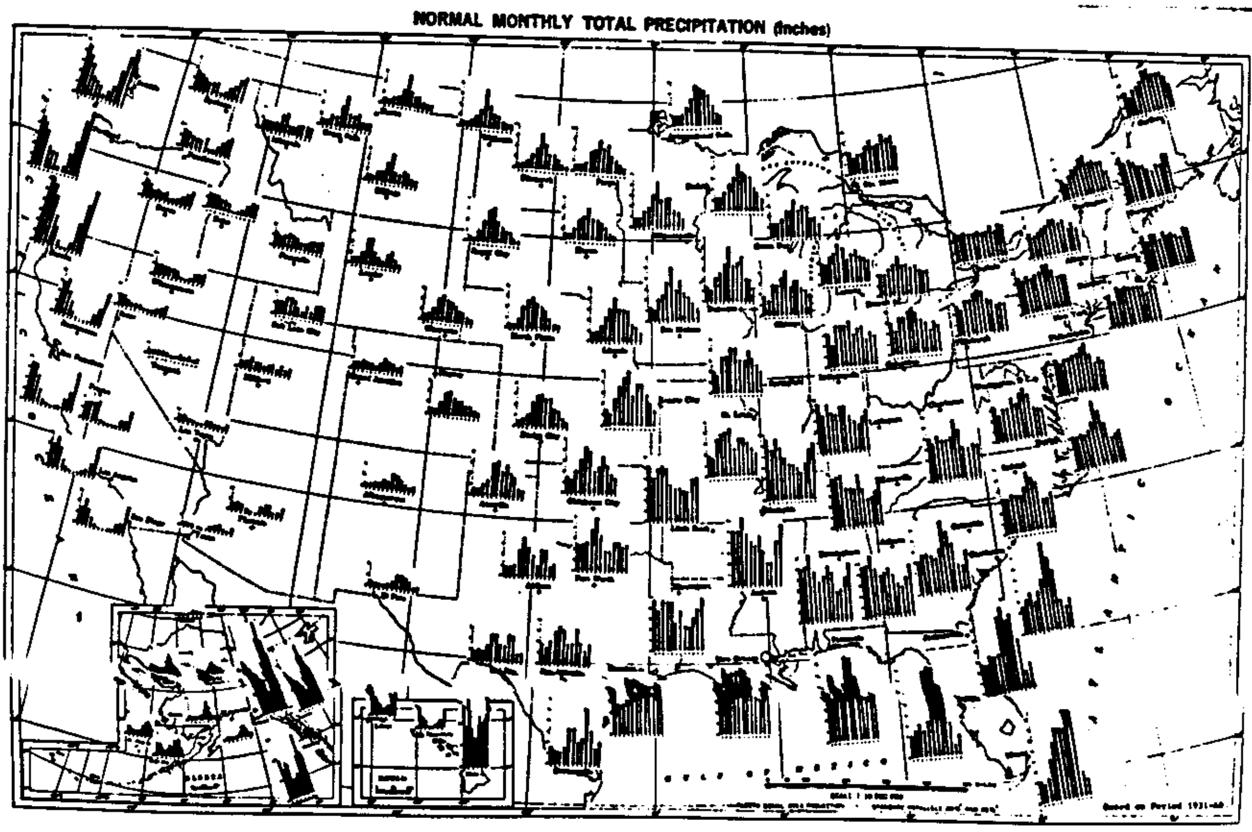

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